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Report of the Sub-Committee on Crushed Stone

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Scope of the Report

The intent of this report is to present information on the characteristics of crushed stone coarse aggregate and, so far as possible, the effects of those characteristics on the properties of concrete.

The subject matter is discussed under the following headings:

1. Classification of rocks.
2. General discussion of rock characteristics.
3. Physical tests of rocks.
4. Properties of crushed stone for concrete for various uses.
   - (a) Unexposed concrete subjected to static and impact stresses.
   - (b) Concrete exposed to the weather.
   - (c) Concrete highways—surface abrasion.
   - (d) Concrete exposed to chemical action.
   - (e) Concrete for water resistance.
   - (f) Concrete for fire resistance.

Classification of Rocks

The following classification of rocks has been proposed by Dr. E. C. E. Lord of the U. S. Bureau of Public Roads (Dept. of Agriculture, Office of Public Roads Bulletin 31, "Examination and Classification of Rocks for Road Building") and will serve to classify rocks used as aggregates.

Table I.

General Classification of Rocks.

Class	Type	Family
I. Igneous	1. Intrusive (plutonic)	a. Granite
		b. Syenite
		c. diorite
		d. gabbro
		e. peridotite
	2. Extrusive (volcanic)	a. rhyolite
		b. trachyte
		c. andesite
		d. basalt and diabase
II. Sedimentary	1. Calcareous	a. limestone
		b. dolomite
	2. Siliceous	a. shale
		b. sandstone
		c. chert (flint)
III. Metamorphic	1. Foliated	a. gneiss
		b. schist
		c. amphibolite
	2. Nonfoliated	a. slate
		b. quartzite
		c. eclogite
		d. marble

The igneous rocks are supposed to have been formed by solidification from a molten state either at the earth's surface or at some distance below. Those solidified at the surface, the extrusive, igneous rocks, have cooled quickly, are rather fine grained, glossy and vesicular or have a porphyritic structure having large crystals in a fine grained ground mass. The intrusive or deep-seated igneous rocks have been solidified slowly and under great pressure. They are generally coarsely crystalline with their constituent minerals well defined as contrasted with the fine grained extrusive rocks. The term "trap" from the Swedish word "trappa" meaning "stair" is commonly applied to the dark-colored igneous rocks such as gabbro peridotite, diabase, basalt and others.

The sedimentary rocks are made up through the consolidation either of the products of former rock disintegration as in the case of sandstone, shale, conglomerate, etc., or from the accumulation of organic remains of a calcareous nature forming limestone or dolomite. Sometimes these materials have been mechanically deposited, at others chemically precipitated as in the case of flint, chert, travertine limestones, etc.

Metamorphic rocks have been produced by the prolonged effect of chemical and physical agencies such as

pressure, heat, moisture, etc., on both igneous and sedimentary rocks. Thus gneiss and schist are metaporphosed, igneous rocks while quartzite, marble and slate have resulted from an alteration of the sedimentary rocks. Some of the metamorphic rocks, such as slate and schist because of their shape after crushing, or due to their structure are not as highly regarded for use in concrete as the igneous and most of the sedimentary rocks.

Obviously the physical properties of rocks are influenced by the characteristics of the component minerals and by the structure of the rock. A thorough understanding of the resistance of any rock must therefore involve a knowledge of the mineralogical composition of that rock and of the properties of the individual minerals. There is some question, however, as to the degree of decomposition any rock will suffer after it is incorporated into concrete as a coarse aggregate, for evidently the mortar offers some protection to the embedded rock.

Physical Tests of Rocks

The physical tests of rocks have been developed for the most part in connection with their road building properties but none the less the tests are in general aimed at the determination of fundamental properties and thus the physical qualities determined by tests give a very fair idea of the degree of resistance of the rock. The tests most commonly employed are the Deval Abrasion Test in which the results are expressed as percentage of wear or french coefficient of wear ($=\frac{40}{\text{per cent wear}}$), the toughness test, the Dorry Hardness Test, the test for crushing strength and the absorption test. These tests have been described in the U. S. Department of Agriculture Bulletin 347.

The results of tests made on thousands of samples of rock show that rocks of all classes range considerably in their physical characteristics. (See U. S. Department of Agriculture Bulletin 370.)

Average results are not of any great value in view of the wide variation from the average to be expected from any particular sample of rock contemplated for a given use, and it thus becomes important to discuss the properties of rock for use as an aggregate from the standpoint of the service it is expected to render. Before leaving the subject of test results, however, the resistance of a rock to freezing and thawing or to some form of accelerated soundness test should be mentioned, as such tests throw considerable light on the suitability of a rock for use as a concrete aggregate, though much remains to be done in formulating proper methods for making these tests and in establishing safe test limits.

Classes of Service to be Rendered by Concrete and the Influence of the Coarse Aggregate

It is obvious that before any consideration can be given to the properties necessary for coarse aggregate it will be necessary to study the various kinds of service which concrete is called upon to render. This subject has already been treated (American Concrete Institute Proceedings, 1926, "What are the Most Significant Tests for Concrete?" by A. T. Goldbeck). It was pointed out that different structures have to withstand different combinations of stresses and that depending upon conditions of service, concrete is called upon to be resistant along the following lines:

1. Compression
2. Tension
3. Cross-bending
4. Shear
5. Impact
6. Surface abrasion
7. Chemical action
8. Freezing
9. Stresses from alternate wetting and drying
10. Absorption
11. Permeability
12. Heat resistance

The Properties of Crushed Stone for Concrete to Withstand the Above Actions

To arrive at the characteristics of stone suitable for concrete it seems entirely proper to consider these characteristics in the light of the service the concrete must render and the above twelve listed forms of resistance include practically all of the conditions to be met in service.

For the purpose of studying the effect of the coarse aggregate on the resistance of the concrete the above individual forms of resistance may be grouped as follows:

(a) Unexposed Concrete Subjected to Static or Impact Stress
(b) Concrete exposed to the weather
(c) Concrete highways—surface abrasion
(d) Concrete exposed to chemical action
(e) Concrete for water resistance
(f) Concrete for fire resistance

(a) *Unexposed Concrete Subjected to Static or Impact Stress*

1. Compression
2. Tension
3. Cross-bending
4. Shear

It is very seldom the case that the crushing strength of stone proposed for use as aggregate is less than that of the strongest concrete made. It would seem logical that so long as the stone has a crushing strength at least equal to that desired of the concrete, the strength of the stone will not be a factor in influencing the strength of the concrete. Some illuminating results on the influence of the coarse aggregate on various properties of concrete are reported in an article entitled, "Wear of Concrete Pavements Tested," Public Roads, May, 1924, by F. H.

Jackson and J. T. Pauls. Fig. 1 is reproduced from this article. It will be noted that although the stone used

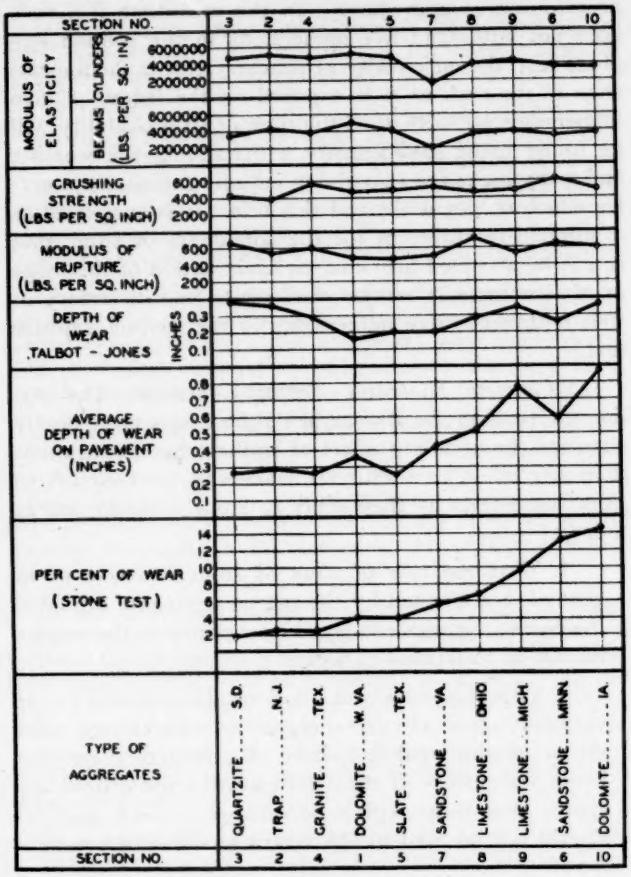

Fig. 1

in the 1:1½:3 mixture of concrete varied in percent of wear (Deval Abrasion Test) from less than 2.0 to over 14.0 the crushing strength of all of the stone concrete was at least equal to 4000 lb. per sq. in. and there was no gerater crushing strength shown by concrete containing the hard tough rocks than by that made with the softest dolomite which had the following characteristics:

Per cent Wear	Hardness	Toughness	Wt. per Cu. Ft. (solid)	Absorption	Grading
14.5	0.0	4	132	8.96	¼-1¼ in.

The crushing strength test was not made on this sample of stone but the above physical values show this rock to be lacking in both hardness and toughness and its crushing strength must also be low, yet the crushing strength of the concrete was apparently unaffected.

In a series of toughness tests made at the Bureau of Public Roads and reported by F. H. Jackson in the July, 1917, issue of the Journal of Agricultural Research, it was necessary to use a 2-in. cylinder of mortar 2 inches in height rather than the customary 1-in. x 1-in. cylinder as used in the toughness test for rock because all mortars were less tough than the weakest rocks ordinarily used commercially.

Prof. F. E. Giesecke, University of Texas, has published data (Engineering News-Record, June 29, 1922) showing that with crushed stone ranging in crushing strength from 4400 to 33,600 lb. per sq. in. the crushing strength of concretes containing 6, 8, 10, 12 and 14 sacks of cement per cu. yd. of concrete were practically identical. This was so even when the strength of the concrete greatly exceeded that of the aggregate.

It would seem that if the rock used as the coarse aggregate is as strong as the mortar portion of the mix the rock will certainly be amply strong. The following test limits are tentatively suggested as satisfying the above requirements:

*Crushing Strength	Per Cent of Wear	Toughness
6000	8 (Fr. Coeff. 5)	5

Cross-Breaking Strength

With regard to the influence of characteristics of crushed stone coarse aggregate on the cross-breaking strength of the concrete, reference may again be made to Fig. 1. Note that the quartzite with a percentage of wear of less than 2.0 produced concrete with a modulus of rupture of over 600 lb. per sq. in. (677), while the softest rock, a dolomite with 14.5 per cent wear made concrete having a modulus of rupture of 599 lb. per sq. in. while the concrete having the highest value for modulus of rupture, 729 lb. per sq. in. had a percentage of wear of 6.3. It is quite evident from the results shown in Fig. 1 that modulus of rupture of concrete made of stone is not a function of the resistance of the stone to abrasion in the Deval Abrasion Test. The dolomite above referred to is far softer than is generally permitted in highway construction and yet it is stronger than the matrix and hence the strength of the concrete has not been affected by its low resistance. This has an important bearing on concrete road specifications, for it is apparent that considering the cross-breaking strength of the concrete alone, the coarse aggregate can be at least as soft as the dolomite above referred to. There are, of course, other factors to consider in connection with aggregates for concrete roads.

Tension

No results have been found to show the influence of the characteristics of crushed stone coarse aggregate on

*Note: U. S. Bureau of Public Roads tests have shown the following results on soft rocks:

Sample Number	State	County	Material	Per Cent Wear	Toughness	Crushing Strength	Absorption, lbs. per cu. ft.
4197	Indiana	Lawrence	Argillaceous limestone	8.1	4	12,250	5.77
5027	Indiana	Lawrence	Limestone	6.4	4	6,900	2.97
5029	Indiana	Lawrence	Limestone	7.6	5	6,450	2.42

the resistance of concrete to direct tension. However, it has been shown that the modulus of rupture is unaffected and since modulus of rupture and direct tension are closely related it can be safely assumed that the tensile strength will be no more affected by the different characteristics of crushed stone coarse aggregate than the modulus of rupture.

(b) *Concrete Exposed to the Weather.*—If in addition to static stress, concrete is to be exposed to the weather then not only should the stone be structurally strong enough but in addition it should be resistant to the effects of the weather. In general, the most rapid weathering proceeds through the disrupting action of frost and of crystalline deposits within the pores and such actions are possible only where water is permitted to be entrained within the concrete mass. It has been shown that limestone, sandstones with a calcareous binder and even other rocks might be subject to decay due to the disrupting effect of calcium sulphate formed by the combination of sulphur dioxide with calcium carbonate in the presence of air and moisture. In the case of rocks other than limestone or calcareous standstone the lime necessary for the formation of calcium sulphate is supplied from the cement. High porosity would accelerate such action. (See Rock Products, Oct. 16, 1926, p. 94.) This applies more particularly to exposed building stone rather than to aggregate well protected with mortar.

Rocks having a high percentage of absorption and which at the same time are structurally weak are apt to weather rapidly. It is also claimed that there are some rocks which because of the presence of seams are apt to take up water and cause trouble through expansion of the concrete surface. Some types of shale also break down very quickly and an instance is noted by J. C. Pearson and G. F. Loughlin of the deleterious effects of a soda lime (labadorite) of the altered plagioclase variety. ("An Interesting Case of a Dangerous Aggregate," by J. C. Pearson and G. F. Loughlin, American Concrete Institute Proceedings, 1923.) An attempt is made to detect all unsound aggregates either by a freezing and thawing test or by an accelerated soundness test such as the sodium sulphate test.

Other soundness tests which have been proposed are:

1. The freezing and thawing test.
2. The sodium chloride test.
3. The alkali test.

(See Proceedings of the Highway Research Board, 1924, p. 109, "Soundness Tests for Coarse Aggregate," by M. O. Withey.)

A number of tests for soundness of rocks made by the Minnesota Highway Department are also reported in the 1924 Proceedings of the Highway Research Board but are not conclusive in showing any relation between physical characteristics of rocks and soundness.

It is quite evident that much remains to be done in the development of a truly satisfactory test for the soundness of coarse aggregates. In the meantime if a rock does not withstand five immersions in the sodium sulphate test, the only really satisfactory test is the appearance of the rock as it is exposed on the ledge. If five immersions are withstood the rock in all probability will be found to be satisfactorily withstanding the weather and many rocks are also giving entirely satisfactory service which do not withstand this test. It is suggested as a suitable requirement for the soundness of stone that it will be accepted provided an examination of the ledge or of structures in service shows it to be satisfactory or if it withstands five immersions in the sodium suphate test.

(c) *Concrete Highways—Surface Abrasion.*—The Arlington Tests of the Bureau of Public Roads more nearly simulate the abrading effect of traffic on concrete roads than any other tests thus far made and the conclusions from these tests as they apply to stone concrete are as follows:

"1. That the rate of wear of stone concrete is, in general, not affected by the coarse aggregate provided the coarse aggregate is equal or superior to the mortar matrix in resistance to wear.

"2. That excessive wear will result from the use of very soft stone as coarse aggregate even though used in conjunction with a mortar of satisfactory quality. From the results of these comparative tests, it would appear that stone with a percentage of wear over 7.0 should not be used in the wearing course of concrete roads.

"6. That small amounts of shale occurring in the coarse aggregate will cause both excessive and uneven wear.

"15. That the Talbot-Jones wear test is not, in general, an indication of the wear which takes place under traffic.

"16. That neither the crushing nor the transverse strength of concrete is a measure of its wear-resisting properties."

In drawing the above conclusions the authors considered only the effects of wear when tire chains were used on the wheels. There was no abrasive effect whatever on any of the sections under the action of the equivalent of 150,000 vehicles passing over the same wheel track. The indications are that the actual abrasive wear of rubber tired traffic is a negligible factor. However, the above conclusions are probably generally applicable with exceptions where local economic conditions make such exceptions necessary. For instance, in some localities there is no hard rock, tire chains are little used and the

climate is not cold. Here the above limit of 7 per cent wear might be raised at least to 8 per cent.

D. A. Abrams, Structural Materials Research Laboratory, Lewis Institute, Bulletin No. 10, "Wear Tests of Concrete" states in conclusion No. 10:

> "(10). The quality of the fine or coarse aggregate produced less effect on wear than is commonly supposed. The wearing resistance of concrete is determined largely by the quality of concrete rather than by the type of aggregate. Good concrete can be produced from aggregates which are generally considered inferior, if other factors are properly taken into account."

Obviously where there is very severe abrasive wear to be withstood such as in factory buildings, railroad platforms, particular sidewalks and floors, pavements carrying steel tires or wheels equipped with chains, a hard, tough aggregate is desirable.

(d) *Chemical Action.*—Where concrete is subjected to chemical action the stone should be at least as resistant as the mortar portion of the concrete. For resistance to alkali effects the sodium sulphate test is directly indicative of the quality of the stone and the stone should be equally resistant as the mortar in the sodium sulphate test.

So far as resistance to acids is concerned the same statement should be made—the stone should be as resistant as the mortar and this can be tested on an accelerated scale at least as satisfactorily as in the case of the soundness test. Among the chemicals having a deleterious effect on concrete are alkali and sea-water, animal and vegetable oils, tanning liquors, sulphite liquor, vinegar, sugar solution, molasses and various kinds of acids.

It is suggested as a requirement for stone coarse aggregate for concrete exposed to chemical action: "The crushed stone shall be equally as resistant as the mortar portion of the concrete when exposed to any particular chemical action."

(e) *Water Resistance.*—The coarse aggregate might affect the water resistance of concrete:

1. By its effect on permeability.
2. By its effect on the durability of the concrete.

1. Permeability.—A very comprehensive series of tests was reported by Prof. M. O. Withey in Bulletin No. 1245, Engineering Series, Vol. IX, No. 2, of the University of Wisconsin. It is shown by him that no matter what kind of coarse aggregate is used there is a fairly definite relation between permeability and crushing strength. Properly cured broken stone concrete of plastic consistency is shown to be impermeable when the crushing strength is 2500 lb. per sq. in. The grading of the aggregate to promote maximum density is also important and grading according to Fuller's curve is said to be beneficial. The characteristics of the concrete rather than the characteristics of the aggregate seem to be most important in producing impermeable concrete. However, soundness is an important characteristic and should be required of stone subjected to water action.

2. Resistance of Aggregates to Water Action.—If the concrete is impermeable, water action then becomes primarily a surface phenomenon, except in the case of very porous and absorbent concrete. Its effects are chemical and physical. So far as the dissolving action of water is concerned, this is negligible on stone which will withstand disintegration in the weather. The percentage of absorption of the mortar matrix is so far in excess of even the softest, sound limestone aggregate that there is little likelihood of the aggregate ever being more soluble than the mortar. Stone aggregate subjected to water action should be sound and have reasonably low absorption for good results in concrete subjected to water action. There seems to be little to fear from the effect of freezing action on the stone in concrete provided the stone is sound, for the mortar is invariably weaker and of much higher absorption than any stone that will withstand the weather. Suggested special requirement:

1. Shall be sound as demonstrated by appearance of ledge or by successful use in structures or by accelerated soundness test.

(f) *Concrete for Fire Resistance.*—Extensive work has been done on the fire resistance of concrete as influenced by the coarse aggregate. This work has been summarized by Committee E-4 on Fire Resistance of Concrete by the American Concrete Institute and that portion of the "Résumé" dealing with aggregates is as follows:

Résumé

"The lessons that may be drawn from the studies so far made by the committee are that the fire resistance of concretes depends to a great extent on the kinds of aggrgates used. Aggregates, such as the siliceous gravels used in the tests reveiwed, result in concretes which are likely to spall rather quickly when exposed to fires. Small percentages of chert or other highly siliceous aggregates mixed with aggregates which do not spall may still cause serious cracking and spalling. Sandstones and granites vary somewhat in affecting the fire resistance of concretes in which they are used as aggregates, but usually the results are slightly better than with the siliceous gravels. Both have the tendency to crack and spall. Hard-coal-cinder concrete does not show this tendency but transmits heat more readily, therefore, does not give longer protection to the steel and structural concrete. Concrete made from blast furnace slag gives results in fire tests about equal to those of trap rock concrete. Both are decidedly better than concretes having the highly siliceous aggregates. In nearly all tests

limestone has been shown to be superior to all the other natural aggregates in its fire resisting qualities. There is little or no tendency for the limestone concrete to spall or crack and its insulating value is generally greater. In fires of long duration the limestone aggregate near the surface becomes calcined and in some cases necessitates more surface repair to the protective covering than where trap rock is used, but these cases are the exception rather than the rule. So far as tests have been made it has been found that for rocks of a given mineral composition those of coarsely crystalline structure are not as resistant to fire as those of fine structure. Broken bricks or burnt clay aggregates give favorable results in strength and fire resistive properties."

All of the foregoing suggestions as to special requirements in specifications for stone are to be regarded as tentative, for they are based on rather meagre information. As additional data are accumulated more definite recommendations will be made possible.

Problems to be Solved in Connection with Specifications for Stone as a Coarse Aggregate in Concrete

1. What is the effect of dust-coated stone on the strength of concrete?
2. What is the allowable percentage of dust?
3. Define stone dust and standardize a method for its determination.
4. Standardize a truly significant soundness test for all aggregates.
5. What are desirable gradings for stone to produce?
   a. Greatest workability of concrete.
   b. Greatest yield.
   c. Greatest strength.
6. What is the effect of unsound particles and how large a percentage is permissible?
   a. In pavements.
   b. In exposed structures.
7. What is the effect of "flat" and "elongated" pieces and what percentage should be allowed?
8. What is a proper definition for "flat" and for "elongated"?

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H. S. MATTIMORE,
R. L. BERTIN,
H. E. BREED,
A. T. GOLDBECK, *Chairman.*

The President's Page

Your President had the very pleasant experience of attending in St. Louis on April 23 a joint meeting of the Mid-West Division of the N. C. S. A. and the St. Louis Quarrymen's Association. Mr. W. R. Sanborn, Vice President of the Northern Region, presided over the afternoon meeting, and although due to certain freight rate matters in which the Chicago producers are particularly interested but few from that city were able to attend, there was nevertheless a representative gathering. Mr. Goldbeck delivered an unusually thoughtful and scholarly address, touching to some extent upon the effect on our industry if certain conclusions are reached as a result of extensive tests shortly to be made known.

The dinner in the evening was attended by about one hundred persons, including the Mayor of St. Louis, the heads of various city departments, and several other distinguished citizens of the community. Colonel McMahon presided as toastmaster admirably and genially. The after-dinner talks possessed the merit of being brief and were also witty and clever. The atmosphere was one of jovial hospitality and camaraderie which every one enjoyed to the full. The St. Louis Quarrymen's Association is actively and effectively engaged in advancing the interests of the local producers through the medium of rendering better service to the users of their commodity. The talent and ability of their Executive Secretary, Colonel McMahon, was freely given to the cause and their association is to be congratulated upon having so diligent and intelligent a director.

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Last year was the first since the birth of the Association that no Membership Committee was appointed. Our reasons for dispensing with the service of such a committee last year have been set forth elsewhere. While under that new arrangement the growth in membership of the Association continued at an increasing rate, it was accomplished at the expense of a considerable amount of time of the officers of the Association which, could they have been relieved of this obligation, might have been expended more usefully in other directions. Basically, the Secretary of the Association should be responsible for continued growth in membership. He can not accomplish all that should be done unless he has able and sympathetic assistance.

We have endeavored to place before all of our present members the responsibility which rests upon them to contribute financially on the basis of tonnage as adopted by the Detroit Convention. The only other avenue open to us to not only increase our revenue but to extend the usefulness of the work of the Association is to continue to materially increase our membership. Bearing these things in mind, we have requested Mr. Boyd to act as Chairman of the Membership Committee and have appointed as his colleagues in this work our Regional Vice Presidents, the Presidents of the several local associations and various others prominent in the industry in order to secure a broad geographic distribution of the personnel.

The members of this committee have not been requested to serve and this article is the first notification of their appointment. Realizing, however, the quick response to any appeal for service which the members of our Association so characteristically afford, I trust that the members of this committee will accept this medium of notification of their appointment. The Chairman of the Committee will write the members in some detail as to the procedure to be followed.

It is our hope and belief that when this committee reports at the next convention the increase in membership will be such as to maintain the growth that the Association has experienced during the last several years. It will be observed that some twenty states are represented on this committee. Others may be added from time to time and in this connection we would welcome your advice and suggestions.

MEMBERSHIP COMMITTEE

J. R. Boyd, *Chairman*

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H. E. Hopkins, Cement, Mill and Quarry (*Illinois*)
Nelson S. Greensfelder, The Explosives Engineer (*Delaware*)
Eugene Atwood, Old Colony Crushed Stone Co. (*Massachusetts*)
A. J. Blair, Lake Shore Stone Co. (*Wisconsin*)
C. D. Brewer, Duluth Crushed Stone Co. (*Minnesota*)
L. R. Cartwright, Mid-West Crushed Stone Co. (*Indiana*)
Richard H. Cobb, Piedmont Corporation (*Georgia*)
R. Newton McDowell, Consolidated Crushed Stone Corp. (*Missouri*)
John W. Stull, Liberty Lime & Stone Co. (*Virginia*)
R. B. Tyler, R. B. Tyler Company (*Kentucky*)
Albert Worthen, The Connecticut Quarries Co. (*Connecticut*)
I. W. Wortman, Morris County Crushed Stone Co. (*New Jersey*)
Porter Yett, City Motor Trucking Co. (*Oregon*)

Protecting Children from Blasting Caps

(Prepared by the Institute of Makers of Explosives.)

There are approximately 500 children crippled each year in the United States by playing with blasting caps which they have picked up in the vicinity of mines, quarries, or in the fields where agricultural blasting has been done.

This means that there are approximately 500 children who will have to go through life with mangled hands, faces, arms and legs. Some of them are killed.

Blasting caps contain fulminate of mercury, a quick, powerful explosive. It is readily exploded. It will explode when struck by a hammer. The blasting cap will explode when thrown into the fire. It will also explode when children try to extract the contents with a pin, or by holding a lighted match to it, or by thrusting the flaming end of the match into the cap. In the mines and quarries, even, where the men who have to use blasting caps every day ought to know better, there are plenty of mangled hands and other injuries as the result of crimping caps on fuse with a jack-knife, pointed nail, or any tool that's handy. Many a miner has crippled himself for life in biting the cap on the fuse, and others have filled themselves with copper or have been killed outright by the sparks from their hat lamps or pipes dropping in an open box of caps. Lots of blasters continue to bite the caps on the fuse and think that because they have never exploded them they never will; but some day they will bite the business end and lose something besides teeth. It is much easier, and lots safer, to use a crimper, a tool made for the purpose. Accidentally stepping on a cap will often result in a mangled foot. Sparks, flame, heat, blows, friction,—all serve to explode the cap to which they are applied.

Boys often play in and around quarries on Sundays and sometimes pick up stray caps and start to investigate them. It is the rarest thing that they ever do this without getting hurt. They perhaps know they are dangerous, and that a spark or a blow will explode them; but they do not realize how sensitive they are, how violent the explosion, or how the pieces of copper fly. Even the name is misleading in this respect. The word "caps" suggests the paper caps used with toy pistols, and because the blasting caps are called by this name it is natural to think that the two articles belong to the same family. They may; but they bear about the same resemblance to each other that a hungry, man-eating tiger does to the gentle pussycat.

If all the children mangled during the past year by blasting caps had been hurt at one time, what an impression would have been created! But because the accidents are spread all over the country and happen at the rate of only about forty or fifty a month, nothing is done. Indeed the best thing to be done is to educate the whole population to realize how dangerous these exceedingly useful things are when they are out of their proper place, and what a dreadful thing it is going through life crippled or blinded for want of a little care and knowledge.

A blasting cap is a copper shell about a quarter of an inch in diameter and an inch or two long, half full of fulminate of mercury. This fulminate is the most sensitive and about the most impulsive explosive in common use. Blasting caps contain anywhere from 15 to 30 grains of it; primers for firearms cartridges usually contain not more than 1/5 grain. That's what the hammer or firing pin of a gun or pistol hits to ignite the powder in the shell. A blasting cap is meant to work the other way. The powder from the fuse ignites the fulminate in the blasting cap, and it explodes with terrific force and detonates the dynamite. The explosion of the fulminate is so exceedingly quick that the flying particles of copper will imbed themselves in iron a foot away. They will blow a hole clean through a steel plate one-sixteenth of an inch thick. A box of caps will blow a hole right through a two-inch oak plank. One cap will blow a child's hand off. Lingg, one of the Chicago anarchists, committed suicide by biting a blasting cap between his teeth.

The point to be remembered is that when a blasting cap goes off it does great damage locally. There is no escaping its effects. Among all the accidents reported from playing with blasting caps, there are only two or three in which somebody was not hurt.

Electric blasting caps are as strong as ordinary blasting caps; but as the capsule or shell is sealed up with a sulphur plug through which the wires are carried down to the fulminate, not so many accidents occur in playing with them. They are generally dipped in dark-colored wax, and are not such attractive playthings as the bright copper blasting caps; but "They get there just the same." Amateur electricians are earnestly advised to bury the electric cap a foot or two in the earth before trying to pass electric currents through the wires, and they had better not do it then. Don't open it up to see what's in it! Don's carry caps around in your pockets! Don't take them home with you! Don't leave them where children can get at them! *Don't monkey with them!*

Local Association Activities

MID-WEST DIVISION AND ST. LOUIS QUARRYMEN'S ASSOCIATION HOLD JOINT MEETING

As has been the custom for the past two or three years, the Mid-West Division of the National Crushed Stone Association and the St. Louis Quarrymen's Association held their annual spring meeting together on April 23 at the Jefferson Hotel, St. Louis, Missouri.

Mr. W. R. Sanborn, Lehigh Stone Company, Northern Regional Vice-President, presided at the business session which was held in the afternoon.

Mr. Sanborn brought to the attention of the meeting that legislation was contemplated in Illinois which would require the crushed stone operators of the state to submit tonnage reports. After discussion the meeting voted as being opposed to the proposed legislation and vested in Mr. Sanborn the power to act on their behalf.

A. T. Goldbeck, Director, Bureau of Engineering of the National Association, spoke on the use of crushed stone as an aggregate in various types of concrete construction, including highways, concrete exposed to chemical action, concrete for water resistance, and concrete for fire resistance. Some excellent discussion resulted from this talk which was both interesting and valuable.

Short talks from President Graves of the National Association, and Col. McMahon, Executive Secretary of the St. Louis Quarrymen's Association, concluded the business meeting.

The Annual Banquet held in the evening was an event that will long be remembered by those who were privileged to be present.

At the conclusion of the dinner, Col. McMahon, who handled the difficult task of Toastmaster in a highly commendable manner, introduced the first speaker of the evening, the Hon. Victor J. Miller, Mayor of St. Louis. Other speakers included the Hon. Edmund J. Kinsey, President, Board of Public Service, who told of the work being done under the supervision of the Board as authorized by the $87,000,000 bond issue of the City of St. Louis; Capt. Robert R. Brooks, Director of Streets and Sewers, who paid high tribute to Mr. Goldbeck's ability as a highway engineer; N. C. Rockwood, Editor-Manager, Rock Products; Otho M. Graves and A. T. Goldbeck, of the National Association; and many others whom lack of space does not permit us to mention.

The entertainment features were decidedly successful, which was due in large part to the efforts of the Committee on Arrangements, composed of J. W. McCullough, Chairman, and Messrs. Bambrick, McKelvey and Olliges.

SOUTH ATLANTIC PRODUCERS FORM ASSOCIATION

The initial steps in organizing the newly formed South Atlantic Crushed Stone Association were taken at a meeting held at Greenville, South Carolina, on March 1st, at which time the following officers were elected:

President—T. I. Weston, Columbia, S. C.
First Vice-President—Lon White, Woodleaf, N. C.
Second Vice-President—W. H. Cook, Greenville, S. C.
Secretary—Richard Simons, Columbia, S. C.

The second meeting of the Association, held on April 18th at Columbia, South Carolina, was largely devoted to the drafting of a Constitution and By-Laws and to a discussion of policies. J. R. Boyd, Secretary of the National Association, was present and gave the meeting the benefit of the experiences of the various other local associations in promulgating their constitutions.

The National Association wishes to most heartily congratulate the Southeastern producers on the organization of the South Atlantic Crushed Stone Association. This is certainly a step in the right direction and one which the National Association will exert every effort to encourage.

AUTO REGISTRATIONS INCREASED 2,000,000

More than 22,000,000 motor vehicles were registered in the United States during 1926, according to reports received from State registration agencies by the Bureau of Public Roads. The year's registration represents an increase of 10.3 per cent or slightly more than 2,000,000 more than that of 1925.

Florida, with an increase of 40.2 per cent, not including nonresident registrations, shows, a greater gain than any other State. Oklahoma, with a gain of 17.8 per cent, and second only to Florida in respect to the amount of increase, was followed closely by Alabama, Idaho, Louisiana, Mississippi, and Utah, all of which had increases over 15 per cent.

Of the total number of vehicles registered, 19,237,171 were passenger automobiles, taxis, and busses, and 2,764,222 were motor trucks and road tractors. The increase in motor trucks and road tractors amounted to 13.2 per cent, which is somewhat greater than the increase for all classes of motor vehicles, indicating a continuation of the development of commodity transportation by highway.

Receipts from registration fees, licenses, etc., amounted to $288,282,352 as compared with $260,619,621 in 1925. Of the gross receipts $190,406,060 was available for highway construction under the supervision of the State highway departments, $51,702,184 was allocated to counties for expenditure on local roads and $25,274,158 was used to finance highway bond issues. The remainder was used for payment of collection costs and miscellaneous purposes.

The CRUSHED STONE JOURNAL
J. R. BOYD, Editor
A. T. GOLDBECK, Director, Bureau of Engineering
The National Crushed Stone Association

CALIFORNIA ASSOCIATION ELECTS C. W. HAY PRESIDENT

At the second annual meeting of the Southern California Rock Products Association, held on May 3, C. W. Hay of the Blue Diamond Company was elected President of the Association, succeeding C. B. Rogers. In addition to Mr. Hay the following officers were also elected:

F. F. Gay, Consumers Rock and Gravel Company, Vice-President.

Paul Graham, Graham Brothers, Inc., Treasurer.

E. Earl Glass, General Manager.

It was our good fortune and pleasure to meet all of these gentlemen when they so hospitably entertained the National Officers on their Western Trip last November and we can therefore say from first hand information that the administration of the Southern California Rock Products Association has been entrusted to exceedingly capable hands.

Paved roads, according to reliable figures, save from 2½ to 4 cents a mile over gravel or dirt roads when they are good, and during recent weeks, we know many who would have saved five, ten, or twenty cents a mile if a paved road had been available.—Minnesota Highway News.

BUILDERS WEAKEN CONCRETE BY USE OF EXCESSIVE WATER

The Bureau of Standards, studying what it calls the yield of concrete, has found that every building job included in its investigations uses too much water, with the resulting effects of less strength and less durable concrete, P. H. Bates, Chief of the Division of Cement, Concrete and Ceramics, recently said orally.

Builders' Costs Reduced

"We are studying the amounts of sand, cement, gravel or crushed stone, and particularly, water, to use in the mixture of concrete. In a number of large concrete jobs that we have been studying in our field investigations, we have found that study of the properties along these lines has enabled the builders to very materially cut down their construction costs and yet to obtain as good, if not better, concrete.

"The Bureau is conducting these researches in connection with, and with the substantial cooperation of, the Portland Cement Association. The work is being done both in the field—in laboratories at Denver, San Francisco, and Northampton, Pa.—and at the Bureau here in Washington.

"While the investigation is not yet complete, there is already sufficient data to warrant the conclusion that every job uses too much water in the concrete mixture, giving low strength and far less durable concrete."

GASOLINE TAX YIELDS $187,603,231

Gasoline taxes yielded a net revenue of $187,603,231 in 1926, according to data collected by the Bureau of Public Roads of the Department of Agriculture from the various States. A tax was imposed in all but four States at rates ranging from 1 to 5 cents per gallon, the average rate being 2.38 cents.

The tax collections indicate that nearly 8,000,000,000 gallons were consumed in the States imposing the tax and it is estimated that nearly 2,000,000,000 gallons were used in the four States in which no tax was imposed.

The revenue from the tax was allocated as follows: $129,441,520 for State highways, $42,609,479 for county and local roads, $5,238,869 for payments on road bonds and $9,313,363 for miscellaneous purposes.

Fewer changes were made in the rate of tax than in other recent years. In Kentucky the rate was increased from 3 to 5 cents, in Mississippi from 3 to 4 cents, in North Dakota from 1 to 2 cents, and in Virginia from 3 to 4½ cents. Other increases which became effective after the close of the year were an increase in Alabama from 2 to 4 cents and in Montana from 2 to 3 cents.

GETTING RESULTS FROM SAFETY WORK

"Getting Results from Safety Work," a recent publication issued by the Policyholders' Service Bureau of the Metropolitan Life Insurance Company, presents for the attention of the executive, an effective series of facts and figures showing the results obtainable from a successful safety program. This booklet is addressed to the Chief Operating Official since it is he who must assume active leadership of plant safety activities if results are to be obtained.

The figures reported to the Bureau show that regardless of the size or type of work, lost time accidents can be prevented. Eighty-one employees of the Neenah Mills of the Kimberly Clark Company worked for 8 months without losing one day as a result of accidents. No reportable injury has occurred among the 600 employees of the Colonie Shops of the Delaware and Hudson Co. during the last 2½ years. No lost time accident happened during two years of the continuous twenty-four-hour-a-day operation of the Furnace Department of the Union Carbide Company.

The returns also showed that from a pure dollar and cents standpoint safety is a worth-while investment. During the period of ten years $9,763,063 was spent for accident prevention work among the subsidiary companies of the United States Steel Corporation. As a result of this expenditure, a saving of $14,609,920 was effected in the cost of injuries to employees. A saving of $70,000 was effected in one year in the cost of accidents occurring among the longshoremen and other employees of the Southern Pacific Steamship Lines through an organized safety movement costing less than $500.

Those interested in the problem of safety may obtain a copy of "Getting Results from Safety Work" by writing to the Policyholders' Service Bureau of the Metropolitan Life Insurance Company, New York City.

ARIZONA HIGHWAY IMPROVEMENT PAYS ENTIRE COST IN ONE YEAR 9 MONTHS, 19 DAYS

An eighty-two mile pavement in Maricopa county, Arizona, paid its entire cost in one year, nine months and nineteen days, according to an article by Ira L. Wood in Arizona Highways.

Mr. Wood uses 2.6 cents a mile as the saving in gas and oil, tires, depreciation and repair bills on the average car, between a paved road and a dirt or gravel road. As authority for this figure he quotes H. G. Borden, former Dean of the College of Engineering, Ohio Northern University.

The Maricopa county road, going east and west from Phoenix, last year carried the equivalent of 816,000 vehicles its entire length. Multiply by 81.9 miles and you get 66,830,400 car miles. At 2.6 cents a mile, the saving to vehicle owners in one year is $1,737,590.40.

The cost of the road is given at $2,866,500 and the interest at five per cent is $143,325. Deducting the interest from the amount saved to motorists, there is a net saving of $1,594,265. Dividing the cost by the saving, he gets the time, quoted above, in which the road pays for itself.

"There are also several items that are not included in this two and six tenths cents," he says. "These you'll have to put your own valuation on. They are discomfort of driving over a dusty, rough road and you might add in a few laundry and cleaning bills when you figure this item and delays due to broken springs or mud holes. In fact, if you have driven much, you can think of a lot of items like this."

NATIONAL SAFETY COMPETITION HONOR ROLL

We are publishing below a list of those member companies which have to date entered the 1927 National Safety Competition and wish to express to them our sincere appreciation of this manifestation of their cooperation in promoting safety.

Rock-Cut Stone Company
- Auburn Quarry
- Syracuse Quarry

Louisville Cement Company
- Speed Quarry
- Milltown Quarry
- Milltown Mine

General Crushed Stone Co.
- Port Deposit Quarry
- Glen Mills Quarry
- Rockhill Quarry
- Mt. Pleasant Quarry
- White Haven Quarry
- Hendlers Quarry
- Geneva Quarry
- Little Falls Quarry
- LeRoy Quarry
- Winchester Quarry

France Stone Company
- Monroe Quarry
- Greencastle Quarry
- Bloomville Quarry
- Dunkirk Quarry
- Middlepont Quarry
- Berlin Quarry
- North Baltimore Quarry
- Holland Quarry
- Waterville Quarry
- Kenton Quarry
- Huntington Quarry
- Bluffton Quarry
- Silica Quarry

American Lime and Stone Co.
- Bellefonte Quarry
- Tyrone Quarry
- Water Street Quarry

Bessemer Limestone and Cement Company
- Bessemer Quarry

John T. Dyer Quarry Company
- Clingan Quarry
- Monocacy Quarry
- Traprock Quarry

Mid-West Crushed Stone Co.
- Greencastle Quarry
- Spencer Quarry
- Ridgeville Quarry

Wickwire Spencer Steel Co.
- Gasport Quarry

Duluth Crushed Stone Co.
- Duluth Quarry

Linwood Cement Company
- Davenport Quarry

Liberty Lime and Stone Co.
- Rocky Point Quarry

Brownell Improvement Co.
- Thornton Quarry

Franklin Limestone Company
- Mimms Quarry
- Franklin Quarry

Lake Erie Limestone Company
- Lake Erie Quarry

CHIPS

Playing Square With a Friend

A St. Paul motorist who had strenuously and successfully opposed a certain bit of paving recently found himself stuck to the hubs at that point. A farmer stood nearby with his team.

"John," said the motorist, "I'm responsible for this mudhole—how much are you going to charge to pull me out?"

"Wal," replied John, "I usually gits three dollars; but I'd sure be a hog to charge a feller anything that has helped me make thutty dollars a day for the last week."—*The Open Road.*

The Cop Knew History?

A motorist was stopped by a policeman on account of poor lights. "I'll have take your name, sir."

"John Smith," was the reply.

"Don't try that on me, sir," warned the man in blue. "I want your proper name and address."

"Then if you must have it it's Abraham Lincoln, Springfield, Illinois."

"Thank you, sir," said the policeman, jotting it down. "Sorry to have troubled you."

"Don't mention it," said the motorist driving on.—*Texas Highway Bulletin.*

Cheap at Half the Price

An artist was employed to renovate and retouch some oil paintings in an old church, and when he sent in his bill of $31.99 was informed that an itemized bill was required. Whereupon the following was duly presented:

For correcting the Ten Commandments	$5.12
For renewing heaven and adjusting the stars	7.12
For touching up purgatory and restoring the lost souls	3.06
For brightening up the flames of hell, putting a new tail on the devil and doing odd jobs for the damned	7.17
For putting a new stone in David's sling and arranging Goliath's head	6.13
For mending shirt of Prodigal son	3.39
Total	$31.99

—*Maine Motorist.*

"So Much" Rope

Willie—"Pa sent me for a piece of rope like this."

Hardware Dealer—"How much does he want?"

Willie—"Just enough to reach from the goat to the fence."—*Exchange.*

In Politics

Auto Tourist: I clearly had the right of way when this man ran into me, and yet you say I was to blame.

Local Cop: You certainly were.

Autoist: Why?

Local Cop: Because his father is Mayor, his brother is Chief of Police, and I go with his sister.—*Texas Highway Bulletin.*

Very Simple

Little Girl (to grandfather): "Grandpa, why don't you grow hair on your head?"

Grandpa: "Well, why doesn't grass grow on a busy street?"

Little Girl: "Oh, I see; it can't get up through the concrete."—*New Hampshire Highways.*

Facts of the Case

Reporter—Were you and Murphy cool and collected after the explosion yesterday?

Flaherty—Well, you see it was this way. I was cool, but Murphy was collected.—*Texas Highway Bulletin.*

Where Desire is Drowsy

Nothing works out right. In a town where you can park as long as you want to there is no reason why you should want to.—*Birmingham News.*

Cruel Thing

At first he acted quite properly. He crooned soft words that were meant for no one else's ears. Gradually she seemed to warm up to his advances. Why couldn't she be like others? Why was she so backward? Finally he lost all control of himself. He spun her around several times. He kicked her none too gently. He grew red in the face and let out several violent oaths. It certainly is hard to start a Ford on a cold morning.—*Carnegie Puppet.*

Hit and Run

Friend—"I suppose you didn't run across a fellow named Scrimshaw on your travels."

Road Hog—"Dunno, old man—I never stop to ask their names!"—*Passing Show.*